Ring Lapping Lab

SONORAN DESERT INSTITUTE

SCHOOL OF FIREARMS TECHNOLOGY

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Introduction

In this lab, we will be discussing scopes, rings, and bases, and their application and selection as well as their history. We will also take a look at the various options for selecting scopes and mounts and how to discuss them with your customers.

This lab will take the form of several discussions with a large block of procedures for you to complete. Procedures are designed to give practical applications of the discussions and are based on real-world experience from a working gunsmithing business.

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Scope History

Ever since long guns were invented, gunners have endeavored to more accurately sight their guns. A detailed history is not necessary at this time, but a brief overview is useful to the working gunsmith, who will encounter many types of scopes, old and new, in the course of their career.

The earliest scopes were nothing more than a hollow tube mounted on top of the barrel of a gun. This did not last long, however, as the invention of the telescope preceded the rifle by over 200 years. Once the rifled barrel came along, shooters finally had weapons capable of accurate shooting past 100 yd., and magnification could be used to good effect. History tells us that telescopic sights and guns were developed almost in tandem.

After the actual sight was developed, the next big advancement was adjustability. While the earliest scopes did have provisions for adjustment, it wasn't until the mid 19th century that accurate, externally adjustable mounts became available. These mounts had both the windage (side to side) and elevation (up and down) built into them.

Some version of the externally adjustable mounts stayed in use through the mid 20th century. This is principally due to the fact that technology had not found a way to make the internally adjustable scopes we are familiar with today and have them stay water-/fog-proof on the inside. Even today, some scope mounts have adjustments built into them to help take advantage of the range of adjustment built into the scope. By zeroing the reticle with the mount, you can center the adjustment on the scope and have the maximum range available to use when sighting-in.

Although there were internally adjustable scopes as early as the late 19th century, they did not become common until sometime after World War II. Adjustment technology suffered somewhat during the early years, and precise adjustment without sticking or moving the incorrect amount was difficult.

As the methods in sealing the scope from outside moisture improved, so did keeping that moisture out. Leupold first pioneered filling the scope tube with an inert gas (nitrogen). There is absolutely no moisture in pure nitrogen, so internal fogging of the lenses — something that plagued scope owners for years — became a thing of the past.

Telescopic sight (German-made ZF Ajack 4×90 (4×38 in modern terminology)) for the World War II pattern Swedish sniper rifle m/1941. Photo courtesy of The Swedish Army Museum.

Fast forward to today, when we have fully adjustable, lightweight, high-quality, fog-proof scopes, capable of being used anywhere from point-blank range to miles away. Truly, there is an optic out there for every gun.

DISCUSSING SCOPES WITH YOUR CUSTOMER

Scope selection is one of the most controversial and hotly debated topics out there. When a customer asks your opinion of what type of glass to put on his gun, ask two questions:

What's your budget? Let's just get this one out of the way. You don't want to get caught showing or recommending a $3,000 scope to a customer with a $500 budget. Knowing how much your customer would like to spend will help you suggest the right scope in their price range and help them get the most bang for their buck.

What will you be using this scope for? This is very important. Even though your customer may be telling you that his best friend recommended the newest, fanciest scope, it may not be what will suit his needs best. Someone who hunts in the Hill Country of Texas will not likely need a 25X scope with a cluttered tactical reticle to make the 75-yd. shots on game so common in that part of the country. Likewise, the tactical competitor will place a premium on clarity and a range-finding reticle on scopes with all the bells and whistles.

Take your time and listen to your customer. Never sell them more than they need, unless they are absolutely set on it. Saving your customers a few bucks now will guarantee they come back to you in the future.

Some customers may ask why your shop charges to mount a scope, when they can go to the nearest large sporting goods store and have the guy behind the counter install the scope they just bought for free. You should tell them that the guy behind the counter may do a fine job of mounting your scope, but you are a professional who has the experience and knowledge to properly mount a scope and avoid any pitfalls associated with almost any type of firearm.

We recommend you develop a multi-step system you can use when describing the precision and intentionality used in your shop when mounting a scope.

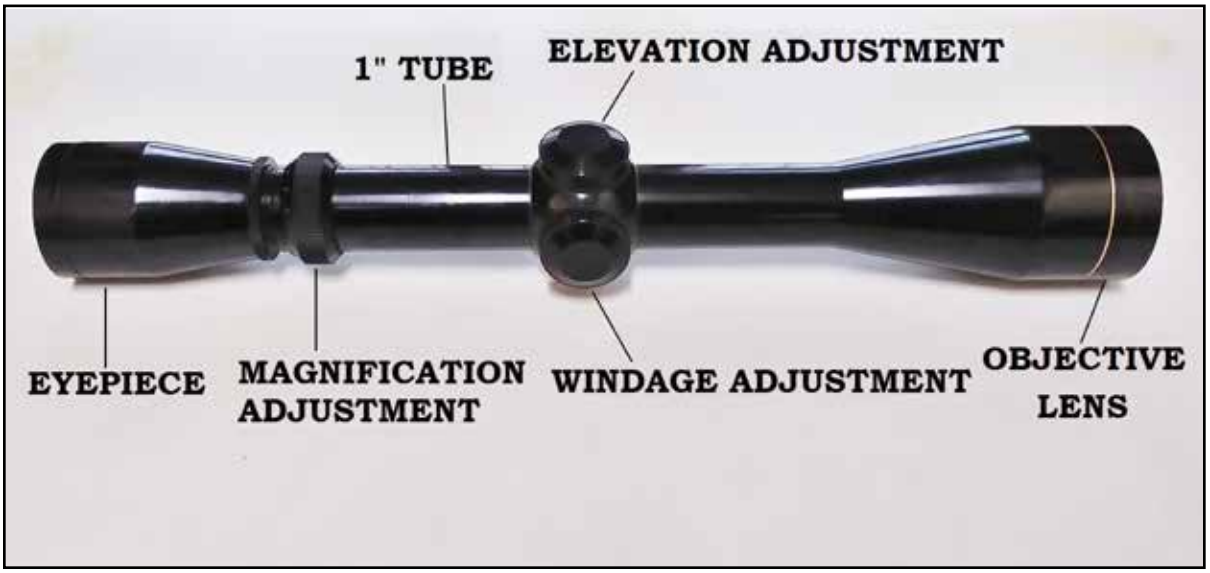

Figure 1: Nomenclature of a hunting-style scope.

Scope Nomenclature

TUBE SIZE

These days, you see scope tubes in two common and three less common diameters. Scopes with 1 in. or 30 mm tubes are the most common sizes (Figure 3), with some rimfire scopes having a ¾ in. tube and some tactical or long-range scopes having 34 mm or 35 mm tubes.

Most people believe that the larger tubes are made that way to gather more light. While that is true up to a point, the size and optical quality of the lenses have much more to do with the light gathering capability of the scope. The real reason for the larger tubes is that they allow a larger windage and elevation system, greatly increasing the range that the scope can be adjusted.

Figure 3: Difference in scope tube size, 1 in. vs 30mm.

OBJECTIVE LENS SIZE

Most hunting scopes come with a 40 – 44 mm objective lens, and that is sufficient for a wide range of hunting applications. Target and long-range tactical scopes typically have a larger objective lens of 50 mm up to as high as 60 mm. On the other end of the scale, close-range tactical and hunting scopes have 20 – 33 mm objectives. Why the difference?

Larger objective lenses give better light transmission in low light situations, though they are limited by the same qualities in the eye of whoever is using them. Larger lenses also give much better optical quality at higher magnifications, making them well-suited to long-range applications. Also, they have more leeway in setting up eye relief.

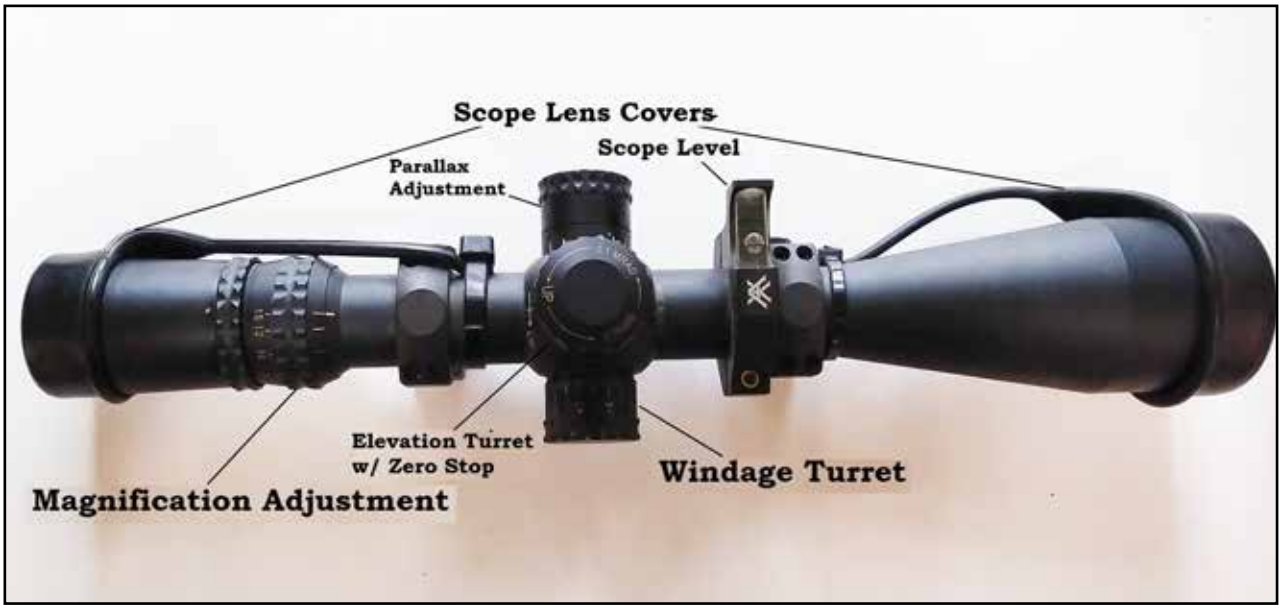

Figure 2: Nomenclature of a tactical-style scope.

Figure 4: A selection of different objective lens sizes.

So, why would you ever want to use a smaller objective lens? One word: weight. Larger lenses are heavier, both because the actual lens weighs more and because the scope that houses it must be bigger. Large scopes on certain guns are not desirable.

Some applications do not require the high magnification of where larger lenses shine, such as with close quarters combat guns or handguns used for hunting.

As stated above, all scope applications must be considered from the point of intended use. A scope that balances weight with the appropriate features will best serve its owner.

EYEPIECE

When thinking about what eyepiece you or your customer wants on your scope, there is one major factor to take into account: How big is it?

Extra large eyepieces can be cumbersome, especially when they get in the way of the bolt handle on bolt-action rifles. This issue is less important if the scope has all the other features you want. You can always mount it a bit higher to be out of the way of your bolt handle.

The other things to look for on an eyepiece is how easily they can turn on variable powered scopes and how well they lock into place once you set your focus or parallax.

Figure 5: Different styles of eyepiece from the same manufacturer.

LENSES

Lens quality is extremely important to the overall desirability of a scope. Lenses can be made of varying quality, and be coated to various degrees.

When talking about lens quality, we are talking about how clear the actual piece of glass is. It is very difficult to get glass so clear that it looks like there is nothing there when you look through it, especially when making it the shape required for scopes.

Coatings on scope lenses run the gamut from plain coated to fully coated, multicoated, and even fully multicoated. Coatings on the lenses make water either bead or sheet off of them so they can still be used in wet weather.

VARIABLE VS FIXED POWER SCOPES

Some scopes have a magnification range that can be adjusted by turning a ring close to the eyepiece or the eyepiece itself. Other scopes have a fixed magnification range and no means for any adjustment.

Until not too long ago, variable power magnification had to work in multipliers of 3x, such as a 3-9 or a 4-12 power scope. Technology has now advanced to the point where we are seeing 4x, 5x, and even 6x magnification ranges, albeit in larger scope tubes.

So, why even consider a fixed power scope, when you can have the versatility of a variable? Well, for one, it is a simpler machine. When in the field, you never have to worry that you'll shoulder a rifle to take a shot at an animal 75 yd. away only to find that you left the scope on 25x from your range trip.

Figure 6: Close-up of the magnification adjustment ring. Magnification levels are clearly marked.

Also, we've found that many hunters typically turn their scope up to its max magnification and this results in missed or wounded game because it was difficult to find the target in the scope.

Snipers and benchrest shooters also commonly use fixed power scopes as they learn every minor detail about their scope, without any variables, and to be able to use it effectively.

FIRST VS SECOND FOCAL PLANE

The important distinction of first or second focal plane has to do with where the reticle is placed in the body of the scope. The practical effect of the focal plane is the size that the reticle appears in relation to the target at different magnifications.

Fixed power scopes do not have a focal plane, as it depends on whether the reticle is placed in front of or behind the erector. The erector is the part of the scope that moves in the tube to adjust windage or elevation.

First focal plane scopes have their reticle placed in front of the erector. This means that the reticle appears to grow and shrink in size as the magnification is changed, when in reality, the magnification is just being applied to the reticle as well as the target. The great advantage of this system is that the reticle will always be proportionally correct, no matter the magnification, and range-finding and MIL-DOT reticles can be used at any magnification range.

Second focal plane scopes have the reticle placed behind the erector and the reticle remains the same size, despite the magnification level. These scopes can still take advantage of range-finding reticles, but only at one certain magnification setting. The biggest advantage these scopes have is that they are still considerably cheaper than first focal plane scopes, though that gap is closing.

RETICLE OPTIONS

There are as many reticle choices out there as you could care to count, available both from the factory and custom manufacturers. Reticles, sometimes referred to as crosshairs, literally started as two thin hairs crossed in the scope. These days, the options have grown exponentially.

Before continuing, it is important to note that the usefulness of any scope or reticle will be curtailed if the reticle is not absolutely level to the gun. A canted reticle throws off the scope's adjustment, especially at longer ranges.

The most common hunting reticle is the duplex. A duplex reticle has thick lines until close to the very center of the scope, where they thin out. This allows for easy target acquisition without obscuring the field of view and a keen shooter can actually learn to range with this scope by figuring out how much the center reticle subtends (distance it covers) at certain distances.

Another common reticle these days is the ballistic drop compensator, or BDC reticle. These reticles have a series of hash marks designed to be used as holdover lines for targets at known distances. There are many proprietary variations of this reticle.

MIL-DOT reticles, or some variation thereof, are useful reticles for tactical or target shooters. These reticles have dots that are the size of a certain number of mils (see below for an explanation of mils) and can be used to tell the range to the target as well as the holdover required to put rounds on target.

Another feature of certain reticles is illumination. For low light shooting, such as varmint or predator control, an illuminated reticle can be a great aid. On quality scopes, the brightness of the illumination can be adjusted, generally by a knob on the left side of the scope. This allows for the use of a reticle that is the correct brightness for the light conditions without being so bright as to wash out or blur the view. Not all illuminated reticles are created equal, and it is recommended that you stick to reputable manufacturers for this feature.

There are so many varied and proprietary versions of the scope reticle that it would be impossible to list them all in the space provided here. Suffice it to say that even once you become familiar with the basics, this is one area in your gunsmithing career you will still have to continually learn the new advancements.

WINDAGE AND ELEVATION ADJUSTMENTS

Hunting scopes generally come with adjustment screws protected by caps that screw onto the scope. These adjustments are designed to be

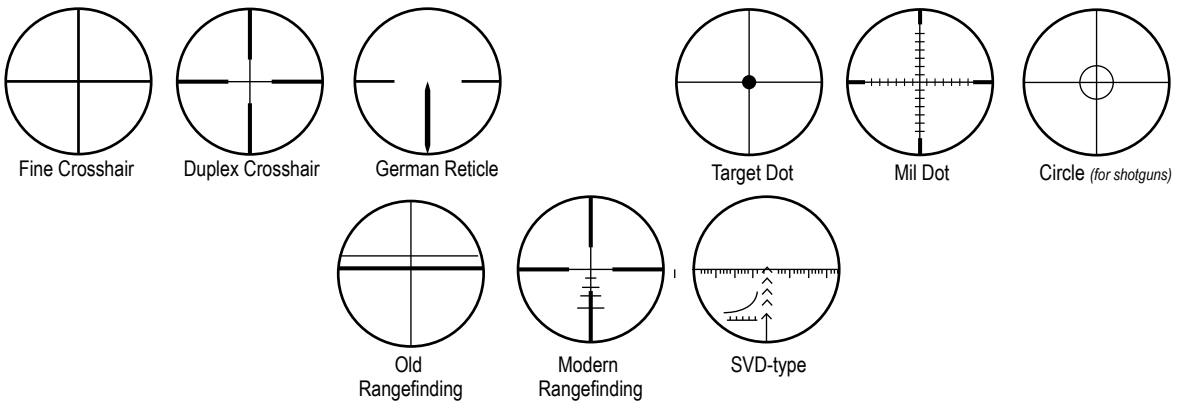

Figure 7: Different styles of reticles available.

Figure 8: External (left) and capped-style (right) elevation and windage adjustments.

set at a specific range and then not altered again. The caps protect the adjustment from moving in the field in case the scope were to bump into something. To adjust these scopes, the caps are removed and the screws are turned either by hand or with a screwdriver (or even a coin) to move the reticle of the scope.

When shooting at longer ranges in varying conditions and distances, an adjustment that is easier to get to is called for. External adjustment with no cap, generally called tactical turrets, can be turned without having to even change shooting positions, let alone removing a cap. These turrets are graduated on the outside diameter and the amount you are adjusting is clearly visible when the weapon is still mounted to your shoulder.

Long-range shooting will often call for the adjustment of the elevation turret for each distance shot as well as to bring your shots on target. So, the ability of a scope to move exactly the same distance with every click every time is vital to this discipline.

Found exclusively on external turrets, a zero stop is a mechanism by which the scope's elevation can be returned to the same adjustment every time. In practice, the rifle is sighted-in at a known distance so the bullets strike the bullseye. Then, the zero stop is set to arrest the rotation of the turret at that particular spot.

For instance, if you sight-in a rifle to hit dead-center at 100 yd., you would need to adjust your elevation to hit dead-center at 500 yd. On a scope with a zero stop, you could raise the elevation turret to allow you to hold in the center of the 500 yd. target. Then, when you went to turn the turret back to its 100 yd. setting, the zero stop would stop the rotation of the turret at that point.

One thing to keep in mind when using or recommending scopes is whether or not you need to use tools to adjust the elevation or windage. As stated above, hunting scopes are usually left alone in the field and the use of tools is not a big consideration. On tactical scopes, however, some turrets need a hex wrench or screwdriver to unlock them for adjustment. Some shooters prefer this, as it ensures the turrets do not move without their knowledge. Other shooters, typically long-range competitors, do not want to have to go to the trouble of using or carrying tools to make their adjustments.

MOA VS MILS

Okay, this one can be tricky to explain, but makes sense once you are familiar with it. Both MOA and mils are about angles in a circle and how far apart those angles are at certain distances. Let's start with MOA.

MOA stands for "minute of angle" and is the same type of measurement as a degree. If you have ever seen a pirate or treasure movie or are familiar with navigation, you have probably heard someone say something like, "The location of the island is 30˚, 16 *minutes,* 30 seconds north, and 98˚, 52 *minutes*, 19 seconds west."

Think about a circle. A circle is divided into 360˚. Each of those degrees is divided into 60 minutes, and each minute is divided into 60 seconds. A minute of angle, therefore, is 1⁄60 of a degree.

Now imagine the line of the bore on a rifle is on a level line. Coming off of the top of that line, right at the muzzle, at an angle of 1⁄60 of a degree, is another line. As you start to move away from the muzzle, those lines separate, and the farther you get away, the farther those two lines are from each other.

It just so happens that these two lines are almost exactly 1 in. apart (actually, 1.047 in.) at 100 yd. As the range increases, so does the distance between the lines, although it is still 1 MOA. At 200 yd., 1 MOA equals roughly 2 in., 1 MOA at 600 yd. is 6 in., and so on.

Mils, sometimes also called mrad, is short for milliradians. Although a little less commonly discussed outside of higher math circles, milliradians are still an angular measurement. A milliradian is one-thousandth (.001) of a radian. But, what is a radian?

A radian is the angle created by wrapping a line equal to the length of the radius of a circle and connecting the two ends of that line at its center.

Let's try and break it down further. The radius of a circle is the distance from its center to the edge. Take a line the exact length of the radius and curve it around the arc of the circle. Now, draw a line from each end of the line you curved around the circle to the exact center of the circle and you have one radian, or 57.3˚. Divide the angle created by those last two lines by 1,000 and you have one milliradian.

It is not necessary to fully grasp the above explanation, so here are the simple numbers:

1 radian = 57.3˚

1 milliradian = .0573˚

so

1 mil = 3.44 MOA

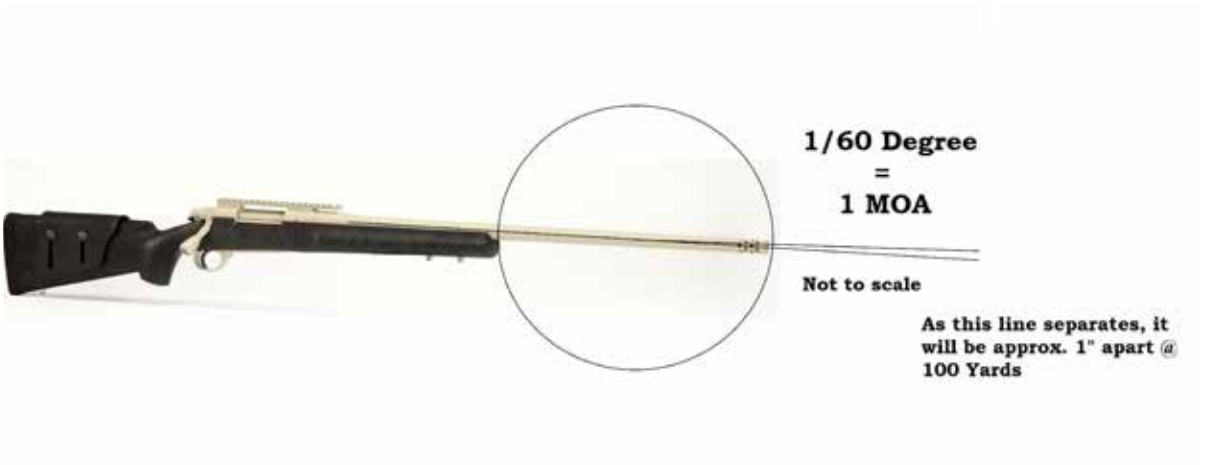

Figure 9: How MOA works.

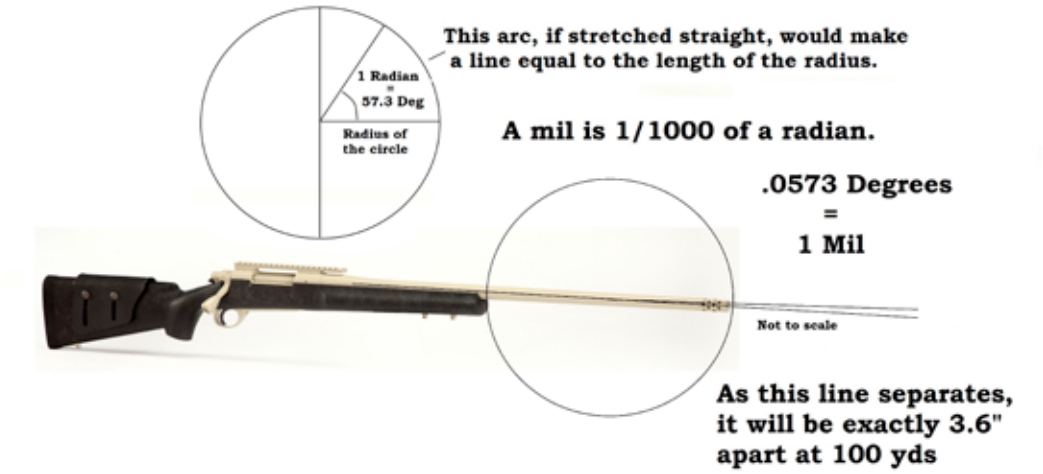

Figure 10: How mils work.

Practically, 1 mil is exactly 3.6 in. at 100 yd. Because mils are widely used in the metric system, you should know that 1 mil = 10cm at 100 m.

Going back to the example of the line in the bore, another line coming off the top at an angle of 1 mil would spread to 3.6 in. at 100 yd.

PRACTICAL USE OF MILS AND MOA

Okay, now that the complicated part is out of the way, how exactly do we use mils or MOA on our scopes for shooting?

Mils/MOA are typically used in three ways. The first way is to measure the group size a gun is capable of. For example, a typical target rifle is expected to shoot groups of shots that, when measured, are no larger than ½ MOA.

The second way is in the adjustment of the scope. The turrets or adjustment screws on a scope are usually set to move the reticle a certain fraction of an MOA or a mil. For instance, you will often see scope adjustments that have hash marks on them. Each hash mark will move the reticle ¼ MOA or ¼ mil, or some other division thereof. Tactical turrets almost always use mils, while most hunting scopes stick to MOA, though that is not a strict rule.

The last way is in the reticle of a scope. MOA reticles will have tick marks vertically, and sometimes horizontally, that are spaced a specific division of an MOA apart. These tick marks are also a specific MOA in length. You will see scopes with reticles that have tick marks placed 2 MOA apart and that are 1 MOA tall or long, as an example.

Figure 11: Elevation adjustment graduated in MOA.

Figure 12: Elevation adjustment graduated in mils.

Mils are usually expressed by small dots in the reticle, hence the term MIL-DOT. Like MOA reticles, each dot subtends a certain number of mils and they are spaced a certain number of mils apart. Mil reticles can be very thorough in how many spots there are to use to measure holdover and distance. For instance, you may see a reticle that has dots that are 2 mils, spaced 1 mil from edge to edge, with a center line ¼ mil thick and the center of the reticle 10 mils wide.

There are scopes out there that have split measurements and will have a mil reticle and MOA adjustments on the turrets. Some shooters are used to this system and will thrive when using it. Just be aware that you need to learn all of a scope's capabilities when either using it or recommending it to a customer.

Understanding, using, and selecting an MOA or mil reticle or scope is not difficult, just involved. Please, continue to build upon the fundamental principles we've discussed by learning more about them. The internet, experienced gunsmiths/shooters, and books are all good places to go for information.

PARALLAX

Parallax, another subject not well understood by most shooters, is the apparent displacement of an object based on the angle at which it is viewed. Parallax in scopes occurs when the target and the reticle are not on the same focal plane. In layman's terms, parallax is when you are looking through a scope and the reticle appears to be centered on the target but actually is not, and moves as you move your eye.

Parallax is almost a non-issue at lower magnifications and shorter ranges. At long ranges, parallax can become an issue, but scopes designed to shoot at those distances generally have a parallax adjustment that brings the target and reticle onto the same focal plane.

We will discuss adjusting parallax in the section on sighting-in.

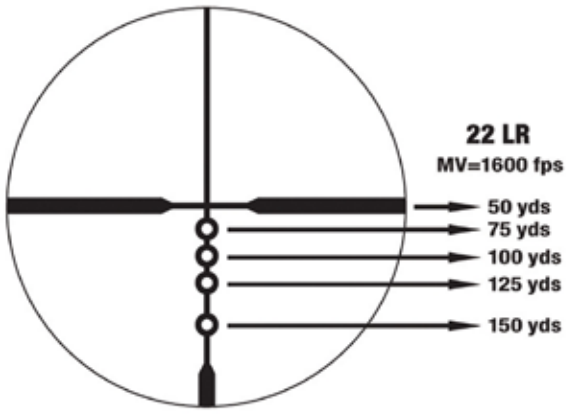

Figure 13: A reticle that is graduated in MOA.

Figure 14: A reticle that is graduated in mils.

Scope Mounted Accessories

LEVELS

In order to avoid canting, or tilting when shooting, some scopes have levels mounted on the main tube. These levels attach to the scope like a ring, although they are not attached to the base. Some scope rings do have an integral level, however.

Levels must be mounted to be precisely parallel to the horizontal line of the reticle or their use is diminished. It is best to do this when first mounting the scope.

Recently, scope manufacturers have been experimenting with placing levels inside the scope, so they are viewed through the reticle. This allows the shooter to check level without changing positions. Expect to see more of this in the future, especially on higher-quality, long-range scopes.

Figure 15: A level attached to the scope helps keep everything level when shooting.

Figure 16: A mounted angle cosine indicator.

ANGLE COSINE/ANGLE DEGREE INDICATOR

When shooting up- or downhill, the range of the target according to your rangefinder may not be the actual distance that gravity will affect the bullet. Gravity pulls on your bullet over a flat line, and does not change according to whether the bullet is traveling up- or downhill. When shooting at an angle, the distance that gravity pulls on the bullet is always less than the ranged distance.

An angle indicator, in either degrees or by cosine, may be used to determine at what distance, as the crow flies, your target actually is. These indicators are mounted on the scope base and protrude to one side of the scope for easy viewing.

To determine the true range using an angle cosine indicator, use this formula:

cosine x ranged distance = true distance

For instance, let's say you are shooting at a target that your rangefinder says is 650 yd. away. You look at your angle cosine indicator and it says .94, so you multiply the two and get a true distance of 611 yd.

Figure 17: An example of a secondary sight mounted on a Picatinny mount at an angle.

An angle cosine indicator is more user friendly, as it is easier to calculate true distance using the cosine of the angle. If you use an angle degree indicator, you must first convert the degree measurement into the cosine, so you must usually use these in conjunction with ballistics software or apps.

SECONDARY SIGHTS/OPTICS

There are accessory mounts available to install either open sights or another optic onto a scope. Open sights are not that common, as they are mounted so high that they become very difficult to use accurately.

More common are secondary optics, such as a reflex or red dot sight, mounted on or near the scope. These sights can be mounted either directly to the scope tube or on an extra mount. They are typically set at a 45° angle to the scope and used at shorter ranges. The most common place you'll find these secondary sights is on guns intended for tactical competitions where the range can vary from a few feet to several hundred yards.

SUN SHADES

Some scopes come equipped with tubes that are the same diameter as the objective lens, and thread onto the end of the scope. These sun shades are designed for daylight shooting in sunny weather. They protect the lens from direct sunlight, which can cause the view through the scope to become fuzzy. In military applications, these shades also help conceal any reflection off of an objective lens from the enemy.

Figure 18: A sun shade can be detached from the scope for lower light situations.

Sun shades are not to be used in low light conditions, as they can curtail the light-gathering ability of some scopes. In addition to that, some lower quality scopes can be negatively affected by the use of a sun shade when it comes to the clarity of the view.

SCOPE COVERS

Scope covers come in three variations. One is an elastic band with either rubber or plastic caps that fit over the eyepiece and objective lens. These can either be solid, obscuring the view through the scope, or see-through, allowing a view through the scope. The see-through covers are usually of inferior quality and it is not recommended to use the scope with them installed, except in the most expedient instances.

Another type of cover is the fabric cover. These are typically used for storage and transportation and to protect the scope from scratches, bumps, and dust.

The last type of scope cover is the flip-up type. These covers remain attached to the scope even during use, as they flip up and out of the way so the scope can be used as normal.

When mounting a scope, you must take into consideration whether or not the shooter will be using scope covers, as you may have to put the scope higher in order to allow the cover to fit.

Figure 19: An elastic scope cover protects the lenses when the scope is not in use.

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Scope Rings and Bases

OBSOLETE/ANTIQUE BASES AND RINGS

In the course of your gunsmithing career, you will come across many different variations of the scope mount and ring. Many times, someone inherits a rifle from a relative that has a scope on it that is old and mounted in an unfamiliar fashion. Usually, these people will want to upgrade to a modern scope and mounting system, but you should make yourself familiar with these mounting systems so you can use and remove them.

As we discussed in the section on scope history, many older mounts had the windage and elevation adjustment built into the mount. Other mounts used what were called target blocks to mount the scope directly onto the barrel. In most cases these mounts are obsolete and should be replaced.

The one instance in which you may be called upon to install a scope using an antique mount is in the case of an historical purist. Usually, this type of customer is attempting to recreate an historically accurate weapon and wants to use an original or faithful reproduction of the scope that would have been contemporary to the gun.

BASE STYLES

The scope base is the piece that is integral or mounts to the rifle and to which the scope, in its rings, attaches. When choosing a base, it is important to make sure it fits the rifle, being both true to the center line of the bore as well as level to the receiver.

Bases come in either one or two pieces, with the one-piece base generally being accepted as the more accurate of the two. This is because a one-piece base is already straight by itself and

Figure 20: Selection of scope base types.
From left: Weaver, Leupold/Redfield, Picatinny, side-mount, and angled European styles.

does not have to rely as much on the straightness of the mounting holes in the receiver like two-piece bases.

HOW BASES ARE ATTACHED

Bases are either integral to the receiver, frame, or barrel of a gun, or are attached by screws. The two most common thread sizes for attaching bases are 6-48 and 8-40. Almost all factory guns have 6-48 mounting screw holes, and they are sufficient for most uses. On heavier recoiling or heavily used guns, 8-40 are desired, as they are larger and provide a stronger attachment to the gun.

Let's take a look at some different styles of bases.

WEAVER STYLE

Weaver bases have a flat top, with angled sides for the scope ring to grip onto. They have slots milled in them at two or more points that the cross screw on a scope ring fits into to prevent the rings from slipping on the base.

Weaver-style bases come in one- or two-piece configurations, and they are made to fit many different types of firearms, including shotguns and handguns.

LEUPOLD/REDFIELD STYLE

This style of base has the windage built into it. The front section of the base has a half-round slot into which a correspondingly shaped ring fits. The rear of the base has a flat top with adjustment screws on either side. These adjustment screws fit into slots cut into the rear ring. This allows the screws to be loosened on one side and tightened on the other to move the scope left to right, greatly increasing the range of windage adjustment.

Leupold bases come in one- or two-piece sets, and are most commonly used on hunting guns.

PICATINNY

The Picatinny rail, named for the arsenal that evaluated it for military use, is the most common

Photo by Oleg Volk.

type of mount used on long-range and tactical weapons. AR-style rifles, in the configuration referred to as "flat top," have an upper receiver with an integral Picatinny rail on top.

Unlike the Weaver-style rail, the Picatinny mount has slots milled through the rail every 3/16 in. or so along its entire length. This allows for a wide range of options for placing rail-mounted optics and accessories.

Picatinny rails can be found in use on many places on a gun, and are not just to facilitate mounting a scope. Rail mounts for accessories such as lights, lasers, bi-pods, fore-grips, levels, angle indicators, etc. are all available and becoming the accepted method for attaching these items to firearms.

One other option you will often see on Picatinny rails is built-in MOA. This means that the rear of the base is tilted to be higher than the front, which adds elevation to your scope when shooting at longer ranges. Rails with 20 MOA built-in are the most common.

RIMFIRE/AIR GUN STYLE

Rimfire mounts are most often found as an integral part of the gun's receiver. These mounts are commonly found on air rifles, as well. These mounts are a simple 3/8 in. dovetail that the rings grip onto. There are no provisions for any sort of cross screw, as the recoil of even the largest rimfire round commonly available today does not produce enough recoil to jar the rings loose.

SIDE MOUNTS

On certain guns, mostly older types, the shells are ejected straight up and away from the receiver when the gun is cycled. Obviously, were a scope mounted directly above the center line, ejection wouldn't be possible. The most common example of this is with older lever-action rifles, such as the Winchester 94, that have scopes mounted to the side of the gun's receiver.

On other guns, the receiver is constructed in such a manner that it is not possible to attach a mount directly to its top. In these cases, the mount is attached to the side of the receiver and the scope is held in rings that are cantilevered over the top of the receiver.

With both of these styles, special mounts are needed and rings are available that only fit these specific mounts. Generally, these are some version of the Weaver-style, as this was the most prolific scope mount manufacturer when these guns were being made.

OTHER BASE STYLES

There are several other base styles, mostly integral bases, that you may encounter. We will look at them from most to least common in our experience.

Ruger Bases

- Ruger-style bases are similar to rimfire bases in that they are based on a dovetail cut into the receiver. The similarities stop there, as Ruger bases also have a half-round, angled slot cut into them as well as a slot on the vertical section to accept the particular shape of the rings, allowing them to be tightened.

  Ruger rings are sold individually (as opposed to most rings that are sold in pairs), and must be used according to the type of receiver the rings are going on. The top of the receiver on Ruger's bolt-action rifles is not level, and so different ring heights must be put on the front and rear. Ruger has a chart available online for determining the type of rings needed for each particular application.

Sako/CZ Bases

- Sako (properly pronounced Sah-ko) and CZ bases are angled dovetails, with the thicker portion of the angle at the front of the receiver. The idea behind this is that the rings are pushed up against the angle when mounting and cannot slide forward any farther under recoil. These proprietary bases are usually integral to the receiver.

European Bases

This category encompasses the myriad bases you will find used to attach scopes in the European style. Many interesting and esoteric varieties are used in Europe, but the most common use of these bases in America is on fine, high-end, custom hunting rifles.

RING STYLES

Weaver/Picatinny Style

- These rings have an angled section on each side designed to grip the sides of the mount, as well as a cross screw or bolt designed to fit into a corresponding slot in the mount to prevent slipping under recoil. Weaver rings can be used with a Picatinny rail, but because of the larger angled section on the Picatinny, the reverse is not true.

Leupold/Redfield Rings

- These rings have a rounded stud on the bottom of the front ring and a flat bottom with slots on each side of the rear ring to facilitate windage adjustment in the base.

Rimfire/Airgun

- This type of ring usually has a separate piece attached to one side of the ring that grips the dovetail mount and does not have a cross screw or bolt that goes across the bottom of the ring.

Ring/Base Combos

- As is implied in the name, these mounts are both base and ring in one. These mounts can be advantageous when weight-saving is an issue, as they eliminate all extra parts that add to the overall weight of the mount. The biggest disadvantage of this type of mount is that the scope must usually be removed from the rings to get the mounts off of the gun. This type of mount is a good option for lightweight hunting rifles.

RING OPTIONS

Quick-Detach

- Quick-detach, or QD, rings have some provision for easy removal. Usually some sort of lever is attached to one or both of the rings to tighten and loosen the

Figure 21: Different types of scope rings.
From left: Weaver, rimfire, quick-detach, see-through, Ruger, and Leupold style.

rings in their mounts. The most common application of this ring style is on brush country and dangerous game rifles. These guns are usually used in thick cover where close shots best taken with open or express sights may be necessary. In these instances, the scope may be removed when the hunter knows he may be going into an area where the smaller acquisition and field of view of a scope would be a liability.

Vertically vs Horizontally Split Rings

- In order to mount a scope to rings, it is necessary that the rings come apart to fit over the main tube on the scope. This is either accomplished by splitting the rings vertically or horizontally.

  Vertically split rings must be attached to the scope prior to attaching the rings to the base. It is much more difficult to level a scope in vertically split rings, as loosening the ring on the scope also loosens it on the mount. In addition, it is difficult or impossible to remove a scope from the base without loosening the rings when they are split vertically.

  As you may have guessed, we believe that horizontally split rings are superior to the vertically split type. When using rings split horizontally, the bottom half, or saddle, of the ring may be attached to the base prior to having the scope placed in it. This allows for easier adjustment of ring position and leveling of the rings. Also, the scope can usually be removed from the rifle without taking it out of the rings – a major boon for gunsmiths.

Figure 22: Vertical vs horizontal split rings.

Type of Upper Ring Halves

- The top section of horizontally split rings can come in a few different variations. The top can be one piece or two per ring and can be attached to the lower section by two, four, or sometimes even six screws. The screws attaching the rings sections can be fillister, hex or Torx®.

  In practice, the easiest to install is the single-piece, top half ring with two screws per side attaching the ring halves together. This configuration is not always sufficient to secure a scope on a heavy recoiling gun, however, so rings with more screws may be necessary.

Ring Materials

- Rings are made of two common materials: steel and aluminum. Steel rings have the advantage of being sturdier and stronger, being able to resist recoil very well. Steel rings are heavier, however, and that can be a consideration on a lightweight rifle for something like mountain hunting.

  Aluminum rings have the advantage of being lighter, but are not able to stand up to the same stresses as steel rings. However, the difference is not as large as one might think, as aluminum alloys have come a long way in strength and rigidity.

See-Through Rings

- Some rings are designed with a large space underneath them to allow the shooter to be able to see under the scope and use the iron sights on a gun. With the advent of more reliable scope

technology, these rings have waned in popularity, though some shooters still like to use them.

The biggest problem with using see-through rings is how high they place the scope above the receiver. This means that the shooter must raise their head in order to use the scope, and so this type of ring should be relegated to relatively low-recoil guns so as to avoid being hit by the gun during recoil.

Scope Mounting Tools and Materials

PROPER SCREWDRIVERS

Scope mounts and bases are attached by fillister (slotted), hex (Allen), or Torx bits, and it is important that the driver or wrench used fits the screw properly.

On fillister-head screws, a properly fitting, parallel-sided gunsmith's screwdriver must be used to avoid damaging the screw. Fillister-head screws are the easiest screw to accidentally damage, but hex-head screws are the easiest scope ring or base screw to strip the head on.

When installing a scope, it is recommended to replace hex-head screws with either fillister or Torx screws to prevent the heads from getting stripped, necessitating that the screw be drilled out.

Torx screws are fast becoming the industry standard for scope bases and rings. The star-shaped bits these screws accept are capable of applying proper torque without the head of the screw stripping out.

Figure 24: A leveling system can be used on certain guns to align the scope.

LEVELING KIT

Kits are available to level the gun and scope for mounting. Typically, these kits come with two levels in magnetic bases. In use, one magnet is attached to a level portion of the gun, such as the bolt raceway on a bolt-action rifle. The other magnet is placed on the elevation turret of the scope and the bubbles on each level are matched.

Figure 23: Brownells Magna-Tip screwdriver set. These tools are essential for scope mounting.

These kits can be useful for certain types of mounting jobs, but it is sometimes difficult to find a perfectly flat section of a gun to attach the level to. Additionally, most scope turrets are aluminum these days, so the magnetic base for the other level can't be used and you must struggle with the level wanting to fall off the scope when mounting.

PITCH ANGLE INDICATOR

A pitch angle indicator, of the type typically found in the construction industry, is a great tool for leveling scopes. Although not always necessary, magnetic bases allow an indicator to be held on either the base, bottom ring half,

Figure 25: A pitch/angle indicator.

or scope turret so that the proper angle can be measured. There is no guess work like with a bubble level, and the gun can be slightly canted and the scope still mounted as long as the angles on the rifle and scope match.

PLUMB BOB

Another handy tool for checking whether a scope is leveled is the plumb bob. When still, a plumb bob is perfectly plumb or straight up and down. You can mount the gun as if shooting and check the vertical crosshair against the plumb line to

Figure 26: Rosin helps keep scopes from slipping under heavy recoil.

make sure they line up. This works especially well when the plumb line is a dark color in front of a lighter-colored wall or other background.

ROSIN

Powdered rosin, like the substance applied to violin bow strings, is a great material to use when mounting scopes, especially those on heavy-recoiling rifles. You can purchase rosin from most gunsmithing supply houses.

When rosin is applied between two surfaces, such as between rings and the scope, and pressure is applied, the rosin increases the friction between the two pieces. This helps prevent those surfaces from sliding against one another, which greatly aids in the prevention of scopes slipping in their rings.

TORQUE WRENCH

More than any other part of a gun, scope bases and rings have specific torque requirements. The manufacturer of each ring or base will have their own specs, but the only way to properly apply the correct amount of torque is through the use of a torque wrench.

Figure 27: A screwdriver-type torque wrench.

In the automotive industry, torque wrenches are large tools designed for use on larger bolts and screws. The tools would be very cumbersome and unwieldy if used when mounting scopes, so a smaller torque wrench, shaped more like a screwdriver, is the best tool for this job. A magnetic socket that accepts common ¼ in. shank screwdriver bits can be placed on the wrench and hundreds of different shapes of bits may be used.

To adjust the torque on these wrenches, pull the base of the handle out and turn clockwise to increase the torque and counterclockwise to decrease the torque.

BORESIGHTER OR COLLIMATOR

After a scope is mounted, and in order to save ammunition when sighting it in, the scope is boresighted. This alignment is not as precise as actually shooting the gun and adjusting the scope to bring the rounds on target, but it will get the shooter on paper at 25 yd.

In the past, scopes were literally boresighted, meaning the rifle was placed on a rest and one looked down the bore to center it on a target. Then the scope reticle was adjusted to be centered on the target as viewed through the bore. The major problem with this method is how difficult it is to look down the bore and then adjust the scope without moving the gun at all. Also, this only worked on guns that have bores you can see all the way through from the rear, e.g., bolt-action rifles.

A more precise way of boresighting a gun is by using a collimator. These collimators are usually sold as boresighting kits and consist of an optical grid in a housing that is placed in the bore using a spud or rod. To boresight, one just looks through the eyepiece of the scope and aligns the reticle with the grid in the collimator. Because the spuds do not fit the bore very tightly, and

Figure 28: Magnetic or spud-attached boresighters help roughly align scopes to save ammo when sighting-in.

the fact that it is hard to level the collimator, this method is only a rough adjustment. A gun should never be taken to a competition or hunt if has only been boresighted.

Another, more convenient type of boresighter, is one that attaches magnetically to the muzzle of a gun. These boresighters are even less precise, but can be used on guns like AR-style rifles where the scope must be mounted too high for the collimator, or on guns with a muzzle brake too long for the spud to reach through.

Installing the Base

Materials needed:

- Base and screws
- Cotton-tipped applicators
- Acetone or other degreaser
- Proper screwdriver or wrench
- Torque wrench
- Blue threadlocking compound (optional)

Check for Alignment/Fit

Before you begin, dry-fit the base to the gun. Place the base over the screw holes used to mount it to the gun and turn the screws in to ensure everything fits together and is level.

Tighten each screw individually to make sure that it is tightening the base to the receiver and not bottoming out in a blind hole. Work the action with the screws installed to make sure none of the screws are too long and binding up the action.

Take everything back apart to prepare for assembly.

This is an important step as you don't want to go through all the trouble to clean and install a base only to find that the last screw won't fit or the base isn't straight.

Prepping the Gun

Before installing the base, all of its surfaces and that of the gun must be cleaned of all oils or grease. Dip the cotton-tipped applicator in the acetone and wipe down the parts. This includes all mating surfaces, as well as the internal and external threaded surfaces. Twist the wet applicators into the internally threaded holes to clean them thoroughly.

Figure 29: Be sure the top of the receiver and screw holes are clean before installing the base.

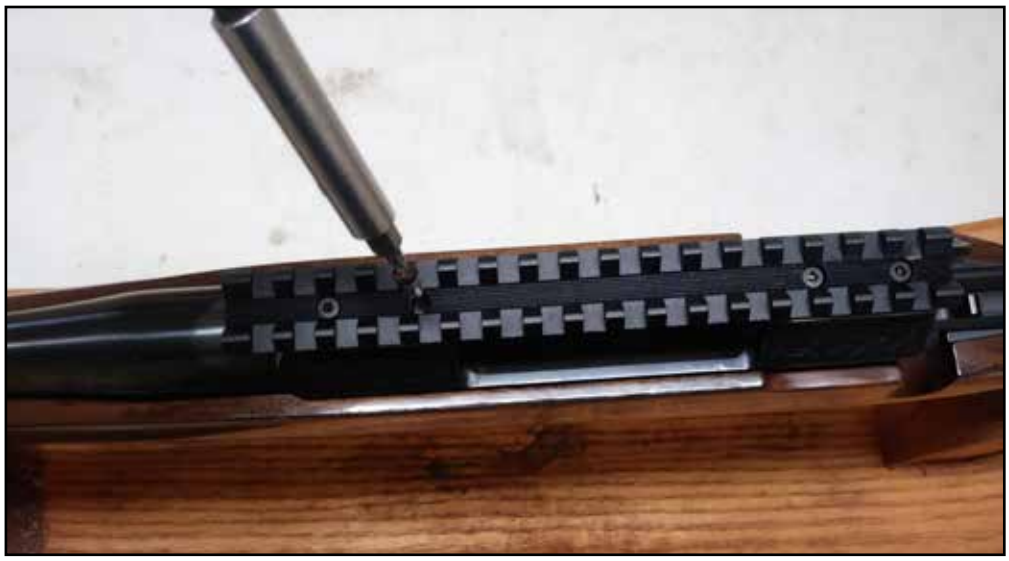

Figure 30: Start the screws and do not tighten them down until they are all installed.

Install Base With Screws

Place the base on the gun and prepare to start the screws in each hole. On lightweight or heavy-recoiling guns, a drop or two of blue threadlocking compound is recommended on each screw. If you are using threadlocker, apply it to each screw as it is installed.

Start each screw in its corresponding hole, but do not tighten any of them until each one is started. This will ensure that each screw fits correctly through the clearance hole in the base.

Tighten each screw by hand until it just stops; we're not applying much force yet.

Torque

Install the proper bit in your torque wrench and adjust the torque to the recommended setting. Tighten each screw a little bit at a time, until the proper torque has been applied.

Remember, if you used threadlocking compound, it can take up to 24 hours to set up and be ready for use.

Figure 31: Torquing the base to the rifle.

Lapping Scope Rings

What is lapping?

Lapping is the precise mating of two surfaces by rubbing them together with an abrasive impregnated compound between them. Scope lapping involves placing a steel bar the size of the scope tube into rings that have a lapping compound in them. These rings are mounted on the base they will be used on and the lapping bar is rotated and moved back and forth to even and true the surface on the ring.

This lapping procedure ensures that the rings are perfectly aligned with one another. This means that when the rings are tightened, no uneven pressure or stress is placed upon the scope tube.

Do You Need To Lap?

The precision of quality scope rings has made lapping less necessary than it used to be, though some shooters and gunsmiths still do it, regardless of the rings used. To determine if the rings need to be lapped, one must first ask about the application vs the time involved.

If an economy scope is being mounted on a rimfire rifle from a big box store, then the time taken to lap is probably not worth it in either time taken or advantage gained. If you are mounting a precision scope on a high-end rifle, there is a way to tell if lapping is needed.

Alignment pins are included in most scope lapping kits. These pins are pointed and can be installed in the rings with the pointed ends facing each other. If the pointed ends are aligned both vertically and horizontally, then lapping is unnecessary.

Lapping Considerations

After you have lapped rings, you must be aware that they are matched to each other and to the base they are mounted on. If you change bases, the rings will need to be relapped. Also, you must be sure to keep the ring halves with the ring bottoms they were aligned to, including keeping the correct orientation.

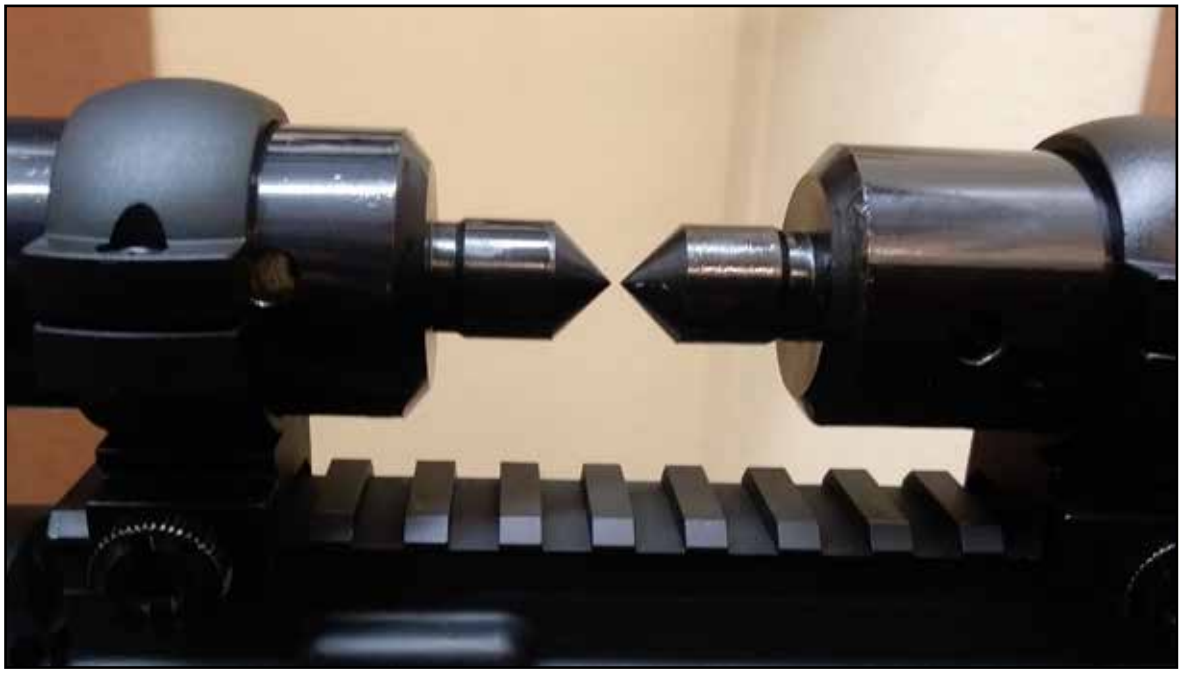

Figure 32: Alignment pins installed in the scope rings. These are aligned pretty well.

PROCEDURE: LAPPING SCOPE RINGS

Tools included in the lapping kit:

- Lapping bar
- Handle
- Alignment pins
- Lapping compound

Also needed:

- Scope base
- Rings
- Acetone or other degreaser

Figure 33: Scope ring halves with lapping compound applied. Ready to lap.

Check Alignment

Mount the rings to the base with the top half of the ring loosely attached. Insert the alignment bars with the points facing each other, and observe the relationship between the points. If the points are aligned, lapping is not necessary, although we will proceed for the purpose of this exercise.

Prepare the Rings for Lapping

Remove the alignment pins from the rings and place them back in the case.

Remove the top half of the ring and apply lapping compound to each half of the ring using a cotton-tipped applicator or craft stick.

Place the lapping bar on the lower ring halves and place the upper ring halves on top. Screw the top half of the rings on, applying enough pressure to tighten the rings on the bar, but not enough to prevent it from moving.

Lap-In the Rings

Attach the handle to the lapping bar and begin moving the bar back and forth, twisting it as you

Figure 34: The lapping bar is rotated and pushed back and forth to lap the rings.

do. You may need to tighten the ring screws as the lapping progresses in order to keep pressure on the lapping bar.

Continue to lap for several strokes and then remove the lapping bar, clean the rings with the degreaser, and check your progress. Be sure to keep the ring halves on the same ring bases and oriented in the same direction throughout this process.

Determining Progress and Completion

Look at the rings and determine how much more lapping needs to be done by how much of the anodized coating has been removed. When 90 percent or more of the inside of the ring is even, lapping is complete.

Caution: Do not lap so far that the rings can no longer be tightened on a scope.

Finish and Clean

After the rings are lapped, remove the lapping bar and clean off all of the lapping compound before removing the handle and placing it back in the storage box.

Thoroughly clean the rings without removing them from the base. Again, be sure to keep the ring top halves with their respective rings.

Figure 35: Even surfaces on the rings after lapping.

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Preparing the Scope for Mounting

Optically Zero

Optically zeroing, or centering, a scope before mounting is important. This procedure ensures that the scope is at its centered factory setting and means you will have adjustment in any direction when you go to boresight or sight-in the gun. There are two ways to optically zero your scope: using a mirror or counting.

The mirror method involves placing the scope's objective lens on a mirror and looking through the eyepiece. Be sure to do this in a well-lit area. The mirror will show a shadow of your reticle if your scope is not centered. Move the adjustments until all you see in the mirror is one solid reticle. Now the scope is optically zeroed.

Figure 36: To optically zero a scope, place it on a mirror in a well-lit room and look through the eyepiece.

Figure 37: The view as seen when looking through the scope on a mirror to optically zero it. This scope is not zeroed.

The counting method involves turning each adjustment out as far as it will go and then turning back the other direction. Count the number of clicks or rotations it takes to get the adjustment to stop going that way. Divide that number by two and back out the adjustment that much. This method is slower, but does not require any other tools or materials.

Check for Turret Housing Clearance

On many modern scopes, the section that houses the turrets is larger than the tube diameter. Be sure that it has enough clearance on the gun you will be mounting it to so it does not touch anything when the rings are tightened on the scope.

This problem is most common when mounting newer scopes on older rifles whose mounting systems were not designed for them.

Check for Clearance of Eye Piece with Bolt

On bolt-action rifles, especially converted military sporters, you must be sure that the bolt can be worked normally without hitting the scope's eyepiece. If the scope does interfere with the bolt handle, either higher mounts or a different shape of bolt handle is needed.

Figure 38: Differences in the shape of turret/adjustment housings. Be sure to select a mount that gives enough clearance for the particular scope in this area.

Check for Room Between Rings

Before you tighten the rings on a base, be sure that the scope you have chosen is long enough to fit on the rings, as they will be attached. This is especially true when mounting a scope with two-piece bases.

PROCEDURE: MOUNTING THE SCOPE

Tools/materials needed:

- Properly fitting driver/wrench
- Level/pitch angle indicator
- Vise or gun cradle
- Rosin
- Torque wrench

Figure 39: Checking for bolt clearance on a rifle scope. This one is good.

Figure 40: Make sure that your scope is long enough for the rings to attach to, especially on two-piece bases. This one barely has enough room.

Considerations for Ring Type

The procedure for mounting scopes can differ according to the type of ring used, usually vertically vs horizontally split rings. For the purposes of this procedure, we will be discussing horizontally split rings.

Check for Level and Set Up

Place the gun in a cradle or vise so you can secure it when it's level. Lay a level on the base and rotate the gun until it is level and tighten the vise. Be sure you are still able to get behind the gun to check the eye relief without removing from the vise.

Installing the Lower Ring Halves

Install the lower rings on the base and check to make sure they are spaced appropriately for the scope you are using. If you previously lapped the rings, they should still be in the position you placed them in for lapping.

Install Scope and Loosely Install Upper Ring Halves

Place the scope on the lower ring halves and roughly adjust it to the position it will be secured in. Loosely install the upper ring halves and tighten them just enough to keep the scope from flopping around, but not so tight that you can't move it (Figures 43 and 44).

Set Eye Relief with All Magnifications

Get behind the gun and check to make sure that you can see the full field of view through the eyepiece of the scope when your face is placed in the shooting position. On a variable powered scope, be sure to check eye relief at the lowest and highest magnification settings, as it can be different for each.

Level Reticle

Place the level on the top turret of the scope. You may need to remove the cap on certain scopes if

Figure 41: Level the rifle. Note the integral Picatinny rail on this AR.

they do not have a flat top surface. Rotate the scope until the level reads the same as it did on the base.

Torque Ring Screws

Set your torque wrench to the appropriate weight and begin to tighten the screws on the rings. Move from screw to screw, gradually tightening them individually. If you tighten one side or the other too much, it can rotate the scope out of level. Continue tightening until the proper torque has been reached.

If you do not have a torque wrench, put a medium amount of pressure on the screwdriver or wrench when you tighten the screws. Do not over-tighten or you could crush the scope tube.

Final Check and Clean

Look through the scope and verify it is still level and the eye relief is correct. Verify that no part of the scope or gun is impeding the function of the other. Wipe the extra rosin off of the scope with a rag or cotton-tipped applicator.

Figure 42: Bottom ring halves installed and rosin applied.

Figure 43: Place the scope on the bottom ring halves and check for correct ring height.

Figure 44: Loosely attach the upper ring halves and set the eye-relief.

The scope is now ready for boresighting.

Variation for Vertically Split Rings

When mounting a scope with vertically split rings, the above procedure is largely the same, with one major exception: The rings must be loosely attached to the scope and both rings and scope go on the base at the same time.

PROCEDURE: BORESIGHTING

Choose the correct spud in the boresighting kit for the caliber of gun you are mounting a scope to and install it in the collimator. Place the spud into the bore of the rifle and look through the eyepiece of the scope. Make sure the reticle in both the scope and boresighter are level and plumb to one another.

Using the turrets on the scope, move the reticle to the center of the grid on the collimator. The scope is now boresighted.

SIGHTING-IN

What Distance?

The commonly accepted distance at which to sight-in a rifle is 100 yd., though this largely depends on the caliber and intended use of the gun. Handguns with scopes may be sighted-in at shorter distances, usually 50 yd. When sighting-in a gun, be sure to know what the appropriate distance is shooting.

Larger caliber rifles may be sighted-in high, about 2 in. high at 100 yd. Since a bullet drops in flight, this means that it will strike the center of a target at a farther distance. In practice, however, it is always recommend to actually shoot at the distance for which you want the gun sighted-in for.

Adjust Parallax

To adjust parallax, first you must determine if your scope is being affected by it. To do this, mount the gun in the shooting position and

Figure 45: Level the scope to the rifle.

Figure 46: Torque the scope rings, moving from screw to screw, turning each incrementally.

Figure 47: Clean excess rosin off for a professional job.

turn the scope to the magnification setting you are going to use. Aim the gun at a target at the distance for which you want to set the parallax, usually long-range.

Move your head around slightly while observing the reticle on the target. If the reticle stays on the same point no matter where you move, your scope is not being affected by parallax. If the reticle seems to float over the target, moving from point to point, use the parallax adjustment knob to remove the parallax from your view.

If your scope does not have a parallax adjustment knob, you can adjust the parallax by adjusting the focus of your eyepiece.

Tracking Test

A tracking test is a shooting test that verifies if your scope reticle moves correctly when adjusted.

To perform this test, take a sighted-in gun and shoot one round at the target. Adjust the scope turrets a certain number of clicks and shoot again. Adjust the turret the same number of clicks in the same direction and shoot again. Continue to do this for a few rounds. If your scope has a zero stop, adjust the turret until it stops and shoot again.

At the end of the test, if your scope is tracking correctly, there should be an equal space between each shot. If your scope has a zero stop, the last round should be in the same spot as the first.

Groups vs Bullseye

When discussing whether or not a gun is accurate, we are not concerned with whether or not it hits the bullseye when shot. Counter-intuitive as it may sound, where the gun is shooting can always be adjusted.

Figure 48: Collimator and spud in use.

Accuracy is referring to the ability of a gun to place multiple shots in the same place (relatively) consistently. This is why the test of a gun's accuracy is in how small a group it can shoot, no matter where it is on the target.

CONCLUSION

As you can see, scope use and selection is a very large topic. New technology is being developed all the time, so you must be aware of the latest advances in order to be able to help your customers decide what optic will best fit their needs. As with everything in gunsmithing, never stop learning!

Figure 49: Tracking test results and final group.

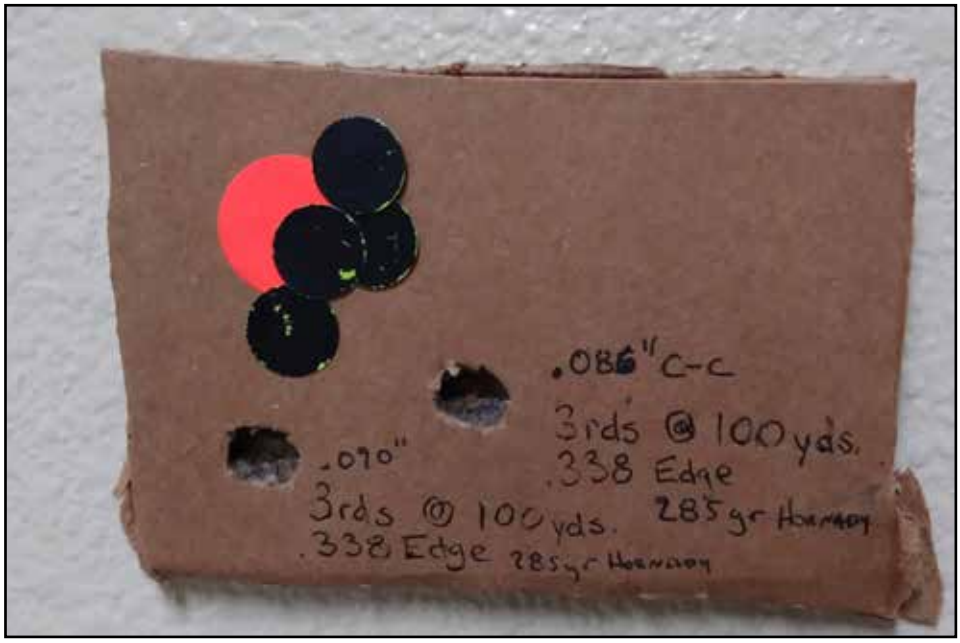

Figure 50: These groups are excellent, even though they are not centered on the target.

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SONORAN
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DESERT
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